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Procedia Engineering 47 (2012) 1191 – 1194

Procedia Engineering

www.elsevier.com/locate/procedia

Proc. Eurosensors XXVI, September 9-12, 2012, Kraków, Poland

Development of gas sensors by microwave transduction with phthalocyanine film

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Abstract

This work presents a new transduction mode for gas sensing using a ***passive microwave*** circuit at ***room temperature***. The design of the sensor includes a microstrip line where is deposited a thin molecular layer of cobalt phthalocyanine (CoPc). The material is sensitive to ammonia and toluene. Submitted to an electromagnetic incident wave in the microwave range, the sensor response is a reflected wave. In the presence of ammonia, the reflected wave is specific to the species concentration. The sensor response is the reflected wave over the incident wave ratio at each frequency traduced by the reflected coefficient. The study deals with the influence of molecular sensitive materials on the sensor response in the presence of ammonia (or toluene) in an argon flow.

Keywords: microwave transduction; gas sensing; phtalocyanine

1. Motivation

With a warning level in air set to 50 ppm, ammonia detection requires new tools, applied to the industrial landfill analysis, in real time. Later, the difficulty to find a selective sensor conducts to develop a set of different sensors such as electronic noses. However, it doesn't respond effectively to the needs of

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doi:10.1016/j.proeng.2012.09.365

selectivity, because of the drift in time of individual elements. Currently, the commercialized gas sensors are based on a conductimetric transduction using non-stoichiometric tin oxide, which presents a long lifespan with a ppm resolution at low-costs [1-3]. The main supplier is the Figaro Company, historical manufacturer who markets the sensors.

2. Principle and experimental device

The new transduction proposed here is based on microwave characterization, which measures the frequency evolution of the sensitive material's permittivity consecutive to the adsorption of molecules on the surface of the sensitive layer at room temperature. The sensor is a passive microstrip circuit, which is matched to conduct to a strong variation of the microwave characteristics of the circuit in presence of a permittivity variation.

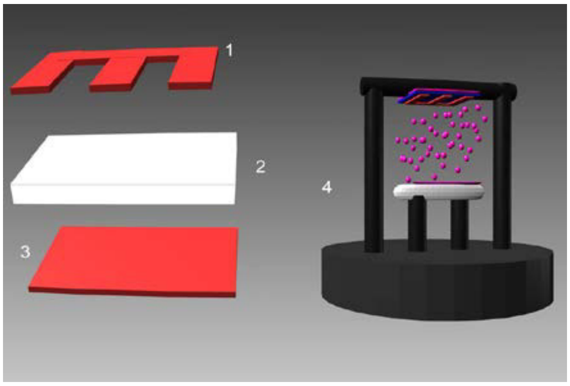

Fig. 1:Schematic conception of microwave gas sensor. 1:copper layer as conductor(20 µm), 2 glass substrat, 3 copper layer as ground,4 sensitive material (CoPc) deposited by thermal evaporation.

The geometry of the propagative structure is a type of microstrip, namely a grounded coplanar waveguide (GCPW) (see left side of the figure 1), where a sensitive material is deposited as thin layer on a glass substrate by sublimation (see right side of the figure 1). Thus, the permittivity variation modifies the characteristic impedance and the propagation constant of the microstrip line that define the sensor.

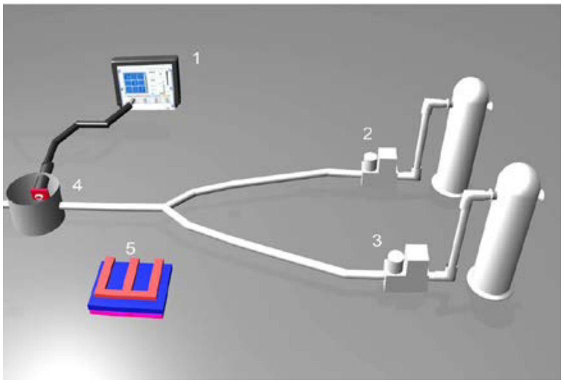

Fig. 2: Schematic experimental device. 1:Vector network analyser (ZVB), 2 and 3 : Mass flow controllers to regulate the pollutant concentration, 4 : test cell, 5 : microwave gas sensor

At each frequency, the wave reflected by the sensor is attenuated and out of phase compared to the incident wave, due to specific gas-sensing interaction with the material. In order to test the sensor, we used two mass flow meters to regulate the concentration in polluting gas. So, experiments were produced with 1 min-long exposure periods under a controlled ammonia concentration in an argon flow, alternating with 4 min-long rest periods under pure argon (Fig. 2). In the case of the toluene exposition, the controlled evaporation and mixing system (CEM) from Bronkhorst is used to evaporate toluene in an argon flow.

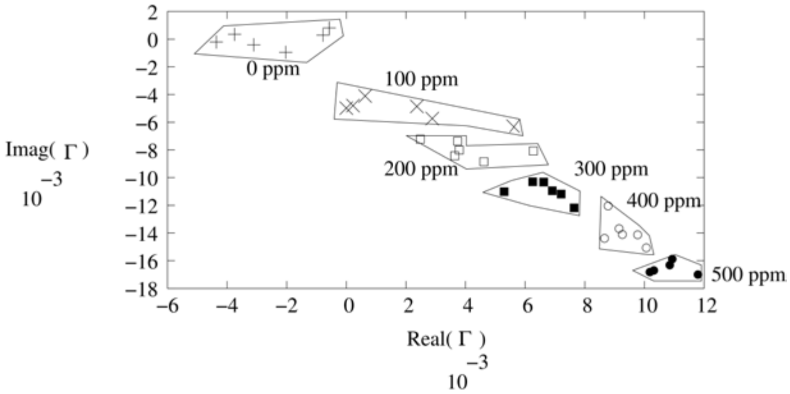

Fig. 3:Imaginary part as a function of the real part of the reflected coefficient Γ, in linear scale, at 6.8 GHz, for a CoPc sensor. The ammonia concentration is indicated [9].

The microwave transduction [4] is applied to the detection of ammonia and toluene in an argon flow using metallophthalocyanines as sensitive materials. Phthalocyanines are a family of sensitive molecular materials used in the development of gas sensors [5-8] at room temperature. The response of the microwave sensor is the reflected coefficient at each frequency, which is a complex number representing the ratio between the incident electromagnetic wave at the input of the circuit and the reflected wave.

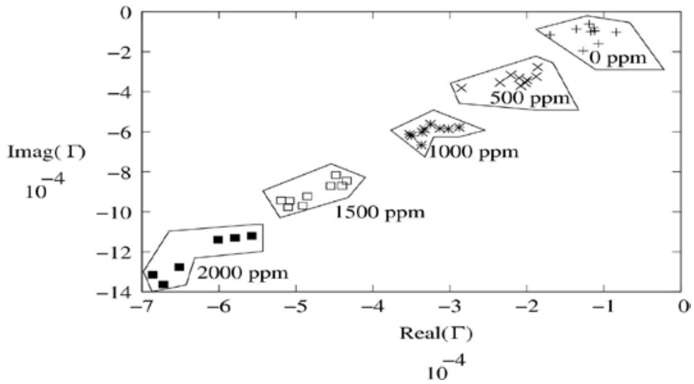

Fig. 4:Imaginary part as a function of the real part of Γ (the reflected coefficient), in linear scale, at 3.9 GHz, for a CoPc sensor. The toluene concentration is in the 0-2000 ppm range.

3. Principle and experimental device

The cycle of exposure to ammonia was made by increasing the concentration from 0 to 500 ppm by 100 ppm steps (100 ppm) and decreasing the concentration (from 500 to 0 ppm) using the same steps. The variation of the imaginary part of the reflected coefficient versus the ammonia concentration is quasi linear (Fig. 3). The plot of the imaginary part as a function of the real part allows to define distinct zones as a function of the ammonia concentration (Fig. 3) [9].

In case of the toluene exposition, the range of concentration is induced between 0 and 2000 ppm with identical steps of 500 ppm. The geometry of the microwave gas sensor is adapted to obtain a resonant frequency near 3.9GHz. The shape of the experimental curve of imaginary versus real part is linear.

4. Conclusion

This work highlights a sensor response to each concentration of ammonia and toluene. The authors are currently working on these issues as well as the interaction mechanism between adsorbed gas molecules and phthalocyanine films and the development of a RFID gas sensor device.

Acknowledgements

The authors acknowledge the Conseil Régional de Bourgogne through the program PARI SMT8 and the Agence Nationale de la Recherche (A.N.R. France) for fundings within the CAPBTX project (ANR-10-BLAN-917-02).

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